Technical Paper 144
UNIVERSITY LIBRARY
JUN 1 1918
PRINCETON N. J.

DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
BUREAU OF MINES
VAN. H. MANNING, DIRECTOR

THE QUICK DETERMINATION OF INCOMBUSTIBLE MATTER IN COAL AND ROCK-DUST MIXTURES IN MINES

BY

A. C. FIELDNER, W. A. SELVIG
AND
F. D. OSGOOD

WASHINGTON
GOVERNMENT PRINTING OFFICE
1918

Generated on 2024-09-28 16:16 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

The Bureau of Mines, in carrying out one of the provisions of its organic act—to disseminate information concerning investigations made—prints a limited free edition of each of its publications.

When this edition is exhausted, copies may be obtained at cost price only through the Superintendent of Documents, Government Printing Office, Washington, D. C.

The Superintendent of Documents *is not an official of the Bureau of Mines.* His office is entirely separate and he should be addressed:

SUPERINTENDENT OF DOCUMENTS,

Government Printing Office,

Washington, D. C.

The general law under which publications are distributed prohibits the giving of more than one copy of a publication to one person. The price of this publication is 10 cents.

2

First edition. February, 1918.

Generated on 2024-09-28 16:34 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google

Digitized by Google

Original from
PRINCETON UNIVERSITY

CONTENTS.

	Page.
Introduction	5
Nature of incombustible matter in coal dust and rock dust	5
Methods of determining incombustible matter	6
Theory of volumeter method	7
Results obtained with Taffanel volumeter	8
Discussion of tabulated results	10
Bureau of Mines modification of Taffanel volumeter	11
Calibration of volumeter	13
Effect of moisture on volumeter results	16
Results obtained with the Bureau of Mines volumeter	18
Effect of variable moisture content	22
Description of portable outfit	25
Equipment included in portable outfit	26
Articles that are kept in stock by laboratory supply houses	26
Articles obtained from other sources or made to order	26
Method of making volumeter determinations	26
Method of calibrating volumeter	28
Determination of specific gravity of coal and rocks with volumeter	30
Qualitative test for coked dust	31
Summary	32
Acknowledgments	33
Publications on the utilization of coal and lignite	34
Publications available for free distribution	34
Publications that may be obtained only through the Superintendent of Documents	35

TABLES.

TABLE 1.	Specific gravities of various rocks and clays found in coal mines or used in rock dusting mines	7
2.	Results obtained with Taffanel volumeter in determinations of percentage of ash and dry shale in synthetic mixtures of coal and shale dusts, series 1 tests	9
3.	Results obtained with Taffanel volumeter in determinations of percentage of limestone in synthetic mixtures of coal and limestone dusts, series 2 tests	9
4.	Results obtained with Taffanel volumeter in determinations of percentage of ash in miscellaneous samples of air-dried road dusts from mines, series 3 tests	9
5.	Calculations showing contractions in volumes when 50 c. c. of alcohols of various strengths are mixed with water	17
6.	Results obtained with Bureau of Mines volumeter in determinations of percentages of dry shale, dry incombustible, and ash in synthetic mixtures of air-dried coal and shale dust from experimental mine, series 1 tests	19

Generated on 2024-09-28 16:34 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

Page.

TABLE 7. Results obtained with the Bureau of Mines volumeter in determinations of percentages of dry limestone and incombustible (ash+CO_2) in synthetic mixtures of air-dried coal and limestone dusts from the experimental mine, series 2 tests 19
8. Results obtained with Bureau of Mines volumeter in determining percentages of ash in air-dried road dusts from various mines .. 19
9. Results obtained with Bureau of Mines volumeter in determinations of percentages of dry incombustible (ash+CO_2) in samples of air-dried road and rib dusts taken in Gallatin mine after rock dusting with limestone 21
10. Results of experiments to determine influence of moisture on volumeter reading 23
11. Data for calibration curves for Bureau of Mines volumeter for use with undried or "as-received" mixtures of Pittsburgh coal dust and shale dust, Pittsburgh coal dust and limestone dust, and miscellaneous road dusts 25

ILLUSTRATIONS.

PLATE I. Volumeter and carrying case 24
FIGURE 1. Curves showing relation between readings of Taffanel volumeter and percentages of ash and dry shale in synthetic mixtures of Pittsburgh coal and shale dust, series 1 tests 11
2. Curves showing relation between readings of Taffanel volumeter and percentages of dry limestone in synthetic mixtures of Pittsburgh coal and limestone dust, series 2 tests 12
3. Curves showing relation between readings of Taffanel volumeter and percentages of ash in miscellaneous road and rib dusts from various mines, series 3 tests 13
4. Details of Bureau of Mines volumeter 14
5. Curves showing relation between readings of Bureau of Mines volumeter and percentages of dry shale, dry incombustible, and ash in air-dried mixtures of Pittsburgh coal and shale dust from experimental mine, series 1 tests 20
6. Curves showing relation between readings of Bureau of Mines volumeter and percentages of dry limestone and dry incombustible in air-dried mixtures of Pittsburgh coal and limestone dust from the experimental mine, series 2 tests 22
7. Curves showing relation between readings of Bureau of Mines volumeter and percentages of dry incombustible and ash in air-dried road and coal dusts from various mines, series 3 tests 24
8. Calibration curve for undried or "as-received" mixtures of Pittsburgh coal and shale dusts used at the experimental mine of the Bureau of Mines 29
9. Calibration curve for undried or "as-received" mixtures of Pittsburgh coal dusts and limestone dusts used at the experimental mine of the Bureau of Mines 30
10. Calibration curve for undried or "as-received" road and rib dusts from various mines 31

Generated on 2024-09-28 16:16 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

THE QUICK DETERMINATION OF INCOMBUSTIBLE MATTER IN COAL AND ROCK-DUST MIXTURES IN MINES.

By A. C. Fieldner, W. A. Selvig, and F. D. Osgood.

INTRODUCTION.

In connection with the extension to various commercial mines of the bureau's experiments[a] on the use of rock dust for the prevention of dust explosions in coal mines it was desirable to use a rapid method for determining in mines the percentage of incombustible matter in the dust collected from roadways. For this purpose the Taffanel[b] volumeter was modified and combined with a compact, portable outfit which could be easily transported to the mines. With this apparatus determinations could be made at the surface, or at convenient stations in the mine, to ascertain whether the desired proportion of rock dust had been added to the coal dust. A detailed description of the outfit, the method of calibration and operation, and the results obtained in its use are given in this paper, in order that mine operators may avail themselves of a simple method of determining the proportion of protective noncombustible material in the road and rib dusts of their mines.

NATURE OF INCOMBUSTIBLE MATTER IN COAL DUST AND ROCK DUST.

The constituents of the dusts in coal mines may be classified as combustible and incombustible, as follows: (*a*) The combustible matter of the organic coal substance comprising various combinations of the elements carbon, hydrogen, oxygen, nitrogen, and a part of the sulphur; usually the greater part of the sulphur is to be considered as combustible, being present in the form of organic sulphur, and iron pyrite (FeS_2) which burns to ferric oxide (Fe_2O_3) and sulphur dioxide (SO_2); (*b*) incombustible matter consisting of clay, shale, slate, and other silicates; silica in the form of sand and quartz grains; calcium sulphate in the form of gypsum, and calcium carbonate in the form of calcite; and (*c*) water or moisture.

[a] Rice, G. S., and Jones, L. M., Methods of preventing and limiting explosions in coal mines: Tech. Paper 84, Bureau of Mines, 1915, pp. 16–21.

[b] Taffanel, J., Expériences relatives au classement des gisements de poussières: Station D'Essais Liévin, 1912, p. 8.

Generated on 2024-09-28 16:16 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

METHOD OF DETERMINING INCOMBUSTIBLE MATTER.

In the usual methods of chemical analysis the incombustible is taken as the sum of moisture and ash in the material analyzed. The percentage of combustible is then computed by subtracting the sum of the percentages of moisture and of ash from 100. The ash is determined by igniting a weighed amount of the sample placed in a porcelain crucible. The crucible is brought to a red heat in a muffle or over a burner, and heating is continued until no further loss in weight is sustained. The moisture is determined by drying a weighed amount of sample in an oven at a temperature slightly above the boiling point of water (105° C., or 221° F.).

Strictly speaking, the percentage of incombustible in a coal-dust mixture is usually somewhat greater than that indicated by adding the percentages of ash and moisture. This discrepancy is due to the fact that certain incombustible constituents, such as combined water in the clay and shale, and carbon dioxide in carbonates, are expelled while the material is being ashed; that is, the ash weighs less than the incombustible constituents that it is taken to represent. Fortunately this error is on the side of safety as regards mine dusts, as it makes the percentage of combustible matter appear slightly larger than it really is. For example, the shale used in the rock-dusting experiments at the bureau's experimental mine at Bruceton, Pa., analyzed as follows:

Analysis of shale used in rock-dusting experiments.

Constituent.	Per cent.
Moisture	1.62
Ash	92.10
Combined water	5.19
Total incombustible matter	98.91
Organic carbon	0.60
Organic hydrogen	.06
Organic nitrogen	.01
Sulphur	.06
Total combustible matter	.73

If the total combustible matter in this shale was taken as 100—(moisture+ash), or 6.28 per cent, the error in calculation was 5.55 per cent.

Where incombustible is largely shale or clayey material, a correction factor of 1.05 may be applied to the ash to include the combined water, as analysis of a number of shales that were considered for rock dusting showed a combined water content of 4 to 6 per cent.

In the analysis of dust mixtures of limestone and coal dust the loss of volatile incombustible matter in the form of carbon dioxide

Generated on 2024-09-28 16:14 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

is so great that the sum of moisture and ash is considerably less than the true incombustible content of the mixture. The method for such mixtures is therefore modified in that the ash is determined by igniting the sample to constant weight at a temperature of 900° C., so that all the carbon dioxide of the limestone is removed. The total percentage of carbon dioxide is then determined in a separate sample, and this result is added to the percentages of ash and moisture. Expressed in formulas, the percentage of combustible matter is calculated as follows:

In mixtures of coal and shale—

$$\text{Combustible} = 100 - (\text{moisture} + 1.05\ \text{ash}).$$

In mixtures of coal and limestone—

$$\text{Combustible} = 100 - (\text{ash at } 900^\circ \text{ C.} + CO_2 + \text{moisture}).$$

For determining very small percentages of combustible matter in rocks suitable for use in rock dusting mines, special methods must be used. These will be described in another report to be issued by the Bureau of Mines.

THEORY OF VOLUMETER METHOD.

The volumeter is simply a specific gravity flask with a graduated stem so proportioned that the volume of a definite quantity of dust suspended in exactly 50 c. c. of alcohol can be measured by reading the meniscus of the alcohol on the graduated stem and referring to a calibration table. After the specific volume has thus been determined, or the specific gravity of the mixed dust, it is possible to calculate to within approximately 5 per cent the percentage of rock dust or ash in the mixture. This relation is due to the decided difference in the densities of coal and rock dust. The real specific gravity of clean coal seldom varies beyond the limits of 1.25 and 1.35. The specific gravities of the various rocks and ash-forming impurities that are found in coal mines are given in Table 1 following:

TABLE 1.—*Specific gravities of various rocks and clays found in coal mines or used in rock dusting mines.*

Rock or clay.	Average specific gravity[a]
Clay	1.9
Soil	2.0
Shale	2.6
Slate	2.8
Limestone	2.7
Sandstone	2.4
Quartz	2.7
Feldspar	2.7
Calcite	2.7
Gypsum	2.3
Mica	2.9
Pyrite	5.0

[a] Trautwine, J. C., Civil engineer's pocketbook, 1909, 19th ed., pp. 214–215; approximate values.

Generated on 2024-09-28 16:17 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

It will be noted that, with the exception of pyrite and some of the clays, the materials are practically twice as heavy as coal dust, and furthermore the numerical values are of the same order. Hence the ash or rock-dust content of any mixture of these rocks with coal dust should be a linear function of the specific volume or specific gravity of the mixture.

RESULTS OBTAINED WITH TAFFANEL VOLUMETER.

The original Taffanel volumeter that was used in these tests consisted of a glass flask of about 50 c. c. volume having a 7 mm. measuring tube fitted to the mouth of the flask with a ground joint. The major part of this tube was graduated into 100 equal parts. The total volume of the flask with the tube inserted was 62 c. c. to the zero mark at the top of the graduated part. The volume to the 100 mark near the bottom of the tube was 57 c. c.

The method of operation recommended by Taffanel[a] is as follows: The measuring tube is removed and 15 grams of dust is introduced into the flask through a small metal funnel; the funnel is then removed and 25 c. c. of ordinary alcohol is allowed to flow onto the coal from a pipette; the measuring tube is then restored to its place and the flask is gently shaken until the dust is thoroughly impregnated with the alcohol and the air bubbles have escaped. Another 25 c. c. of alcohol is then allowed to flow from the pipette into the flask through the measuring tube. The level of the liquid is read on the measuring tube, and by reference to calibration curves or tables the percentage of ash or of rock dust in the mixture is obtained. After the reading has been made, the contents of the volumeter are discharged on a filter, whereby most of the alcohol is recovered for further use.

In this manner tests were made with three classes of materials as follows: Series 1 tests, synthetic mixtures (compounded mixtures, the constituents being weighed and mixed) of coal No. 18457 (7.18 per cent ash) and shale No. 18623 (84.55 per cent ash); series 2 tests, synthetic mixtures of coal No. 18446 (9.48 per cent ash) and limestone No. 18412; series 3 tests, road dusts from various mines. The results obtained are given in Tables 2, 3, and 4 following and in the curves of figures 1, 2, and 3, in which the volumeter readings are plotted as abscissas and the percentages of shale, limestone, and ash are plotted as ordinates.

[a] Taffanel, J., Expériences relatives au classement des gisements de poussières: Station D'Essais Liévin, 1912, pp. 8–9.

Generated on 2024-09-28 16:18 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

TABLE 2.—*Results obtained with Taffanel volumeter in determinations of percentage of ash and dry shale in synthetic mixtures of coal and shale dusts, series 1 tests.*

Mixture.		Calculated percentage of dry shale in mixture.	Percentage of ash in mixture calculated from ash in coal and shale.	Volumeter reading.	
Coal.[a]	Shale.[b]			15-gram sample.	20-gram sample.
Grams.	*Grams.*				
100	0	0	7.2	34.5	.....
90	10	9.9	14.9	45.8	.....
80	20	19.7	22.7	55.5	.....
70	30	29.6	30.4	66.3	.....
60	40	39.5	38.1	77.0	.....
50	50	49.3	45.9	87.3	.....
40	60	59.2	53.6	97.0	.....
30	70	69.1	61.3	.....	55.8
20	80	79.0	69.1	.....	69.8
10	90	88.8	76.8	.....	84.0
0	100	98.7	84.6	.....	97.8

[a] Air-dried coal No. 18457, containing 1.3 per cent moisture and 7.2 per cent ash.
[b] Air-dried shale No. 18623, containing 1.3 per cent moisture and 84.6 per cent ash.

TABLE 3.—*Results obtained with Taffanel volumeter in determinations of percentage of limestone in synthetic mixtures of coal and limestone dusts, series 2 tests.*

Mixture.		Calculated percentage of dry limestone in mixture.	Volumeter reading.	
Coal.[a]	Limestone.[b]		15-gram sample.	23-gram sample.
Grams.	*Grams.*			
100	0	0.0	42.8	.....
90	10	10.0	52.8	.....
80	20	19.9	65.0	.....
70	30	29.9	76.5	.....
60	40	39.9	87.0	.....
50	50	49.8	98.8	.....
40	60	59.8	.....	25.5
30	70	69.8	.....	42.8
20	80	79.8	.....	61.0
10	90	89.7	.....	79.0
0	100	99.7	.....	95.9

[a] Air-dried coal No. 18446, containing 1.2 per cent moisture and 9.5 per cent ash.
[b] Air-dried limestone No. 18412, containing 0.3 per cent moisture and 99 per cent ($ash+CO_2$)

TABLE 4.—*Results obtained with Taffanel volumeter in determinations of percentage of ash in miscellaneous samples of air-dried road dusts from mines, series 3 tests.*

[Fifteen-gram samples used.]

Laboratory No.	Source of sample.	Moisture in sample "as received."	Moisture in air-dried sample.	Volumeter reading.	Percentage of ash.		Difference.[a]
					By volumeter.	By calcination.	
		Per ct.	*Per ct.*				
15483	Owl Creek, Hot Springs County, Wyo.....	13.1	5.6	60.5	22.0	20.0	+2.0
15484	.....do.....	15.7	6.2	53.3	16.0	8.7	+7.0
15485	.....do.....	12.9	5.4	69.3	29.0	25.0	+4.0
17086	Pittsburgh bed, Washington County, Pa....	8.8	1.1	56.5	18.0	19.9	−2.0
17087	Pittsburgh bed, Cincinnati mine, Washington County, Pa.....	6.2	1.2	56.0	18.0	17.4	+1.0
17132	.....do.....	7.9	2.1	70.0	29.0	25.3	+4.0
17133	.....do.....	2.9	2.1	65.8	26.0	23.2	+3.0
17134	.....do.....	6.2	2.5	62.5	24.0	21.9	+2.0
17135	.....do.....	6.2	2.3	77.0	35.0	32.8	+2.0

[a] Average error of volumeter, ±3 per cent; maximum error, ±8 per cent.

Generated on 2024-09-28 16:18 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

TABLE 4.—*Results obtained with Taffanel volumeter, etc.*—Continued.

Laboratory No.	Source of sample.	Moisture in sample "as received."	Moisture in air-dried sample.	Volumeter reading.	Percentage of ash.		Difference.
					By volumeter.	By calcination.	
		Per ct.	*Per ct.*				
17211	Noble mine, No. 7 bed, Noble County, Ohio..	9.3	3.1	88.0	44.0	37.4	+7.0
17212	.....do.....	9.8	3.0	88.0	44.0	39.5	+4.0
17861[a]	Coalburgh bed, Kanawha County, W. Va....	2.8	1.8	52.8	58.0	55.8	+2.0
18076	Jackson County, Ohio.....	6.8	4.2	92.8	47.0	44.9	+2.0
18164	Raton No. 2 mine, Colfax County, N. Mex....	2.3	1.3	89.8	46.0	46.9	−1.0
18165	.....do.....	3.2	1.2	95.8	50.0	51.9	−2.0
18167	.....do.....	2.1	1.4	65.0	25.0	28.2	−3.0
18168	.....do.....	3.5	1.8	79.5	37.0	38.9	−2.0
18170	.....do.....	2.7	1.2	89.0	45.0	47.2	−2.0
18172	.....do.....	3.1	2.0	65.3	25.0	27.2	−2.0
18173	.....do.....	2.5	1.5	56.3	18.0	26.0	[b]−8.0
18176	.....do.....	2.2	1.5	77.0	35.0	37.6	−3.0
18177	.....do.....	2.2	1.6	64.8	25.0	27.5	−3.0
18178	.....do.....	1.7	1.1	95.5	50.0	51.7	−2.0
18179	Raton No. 5 mine, Colfax County, N. Mex...	3.1	1.4	82.0	39.0	40.7	−1.7
18180	.....do.....	6.6	1.7	92.3	47.5	49.1	−1.6
18181	.....do.....	4.2	2.3	78.3	36.0	36.0	−0.6
18182	.....do.....	1.9	1.2	90.5	47.0	48.7	−2.0
18183	Raton No. 2 mine, Colfax County, N. Mex....	5.5	1.3	61.3	22.0	25.3	−3.0
18184	.....do.....	3.8	1.7	94.5	49.0	50.6	−2.0
18223	Shelby County, Ala.....	2.6	1.3	50.5	14.0	14.3	0.0
18372	Helena bed, Acton No. 2 mine, Garfield County, Colo.....	4.7	2.9	43.5	8.0	7.6	0.0
18373	Allen bed, Vulcan mine, Colo.....	4.8	2.9	46.8	10.0	9.1	+1.0
18413	Jagger bed, Tuscaloosa County, Ala.....	3.5	.7	46.3	10.0	12.4	−2.0
18614	Mine No. 6, Lincoln, Wyo.....	4.7	2.0	100.0	54.0	54.2	0.0
18689	International mine, Carbon County, Mont...	9.5	5.8	67.5	27.0	22.0	+5.0
18690	.....do.....	10.9	5.8	80.8	38.0	32.1	+6.0
18758	Pittsburgh bed, Knob mine, Washington County, Pa.....	5.8	1.3	80.3	40.0	34.8	+5.0
19068	Western No. 18 mine, Crawford County, Ky..	5.7	1.5	81.8	39.0	31.6	+7.0
19069	Hamilton No. 8 mine, Crawford County, Ky.	10.6	2.4	63.0	24.0	21.3	+3.0
19368[a]	Williams County, N. Dak.....	18.4	10.7	51.0	57.0	52.6	+4.0
19369[a]	.....do.....	30.5	10.8	54.3	59.0	51.5	+7.0
17775[a]	Road dust from experimental mine.....	8.6	2.2	67.5	66.0	66.3	0.0
18086	.....do.....	2.3	1.4	43.5	8.0	9.9	−2.0
18287	.....do.....	3.0	1.5	92.3	48.0	46.3	+2.0
18333[a]	.....do.....	3.7	1.5	65.5	65.0	65.2	0.0
18364[a]	.....do.....	3.9	1.6	96.3	81.0	81.0	0.0
18377[a]	.....do.....	5.7	1.7	76.3	71.0	70.2	+1.0
18390[a]	.....do.....	3.9	1.5	100.5	83.0	85.1	−2.0
18399[a]	.....do.....	3.9	1.6	99.3	83.0	82.6	0.0
18566[c]	.....do.....	8.9	1.4	56.0	60.0	57.4	+3.0
18575[a]	.....do.....	3.7	1.3	54.3	59.0	61.5	−2.0
19312	.....do.....	3.7	1.7	89.5	45.0	40.7	+4.0
19313	.....do.....	4.0	1.7	90.0	46.0	42.2	+4.0

[a] 20-gram sample used. [b] Evolution of gas obscured volumeter reading.

DISCUSSION OF TABULATED RESULTS.

As would be expected, the indications of the volumeter are closely accurate for the mixtures of coal and shale dust and of coal and limestone dust; in no determination did the volumeter error exceed 1 per cent. In the series 3 tests, which included the wide range of miscellaneous road dusts represented in Table 4, larger errors were found, the maximum error being 8 per cent and the average somewhat less than 5 per cent. These results obtained with American coals agree with results obtained by Taffanel,[a] who states that in testing a large

[a] Taffanel, J., Expériences relatives au classement des gisements de poussières: Station D'Essais Liévin, 1912, pp. 8–10.

Generated on 2024-09-28 16:16 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

number of road dusts from various mines in France the average probable error was less than 5 per cent and the maximum error was less than 10 per cent. These larger variations in the tests with miscellaneous road dusts are due to the differences in the specific gravities of the rock materials in the different mines. For this reason it is advisable to calibrate the instrument directly with the

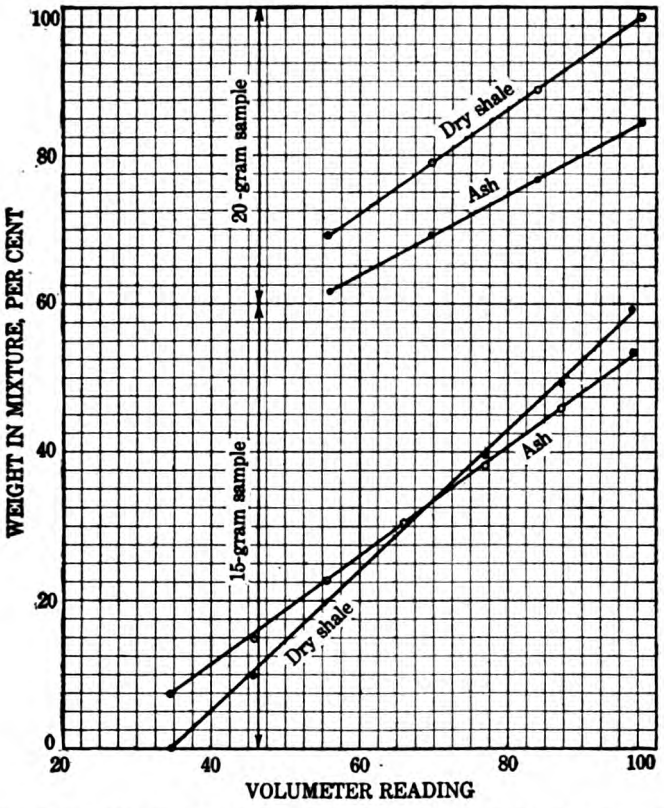


FIGURE 1.—Curves showing relation between readings of Taffanel volumeter and percentages of ash and dry shale in synthetic mixtures of Pittsburgh coal and shale dust; series 1 tests.

particular coal and rock dust that is encountered in the mine in which it is used. With such a special calibration the volumeter should give results accurate to about 2 per cent with air-dried dusts.

BUREAU OF MINES MODIFICATION OF TAFFANEL VOLUMETER.

In using the Taffanel volumeter it was found that the graduated measuring tube was too small to cover completely the ordinary range of densities encountered in road dusts and in rock-dust mixtures.

Generated on 2024-09-28 16:26 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

In the series 1 tests, with mixtures of shale and coal dust, and with 15-gram samples, the level of the liquid did not reach the graduated part of the tube with mixtures containing more than 60 per cent shale. It was necessary to use 20-gram samples to obtain scale readings with the mixtures containing the higher proportions of rock dust. The same difficulty was experienced with mixtures of limestone and coal and with the miscellaneous road dusts, so that two

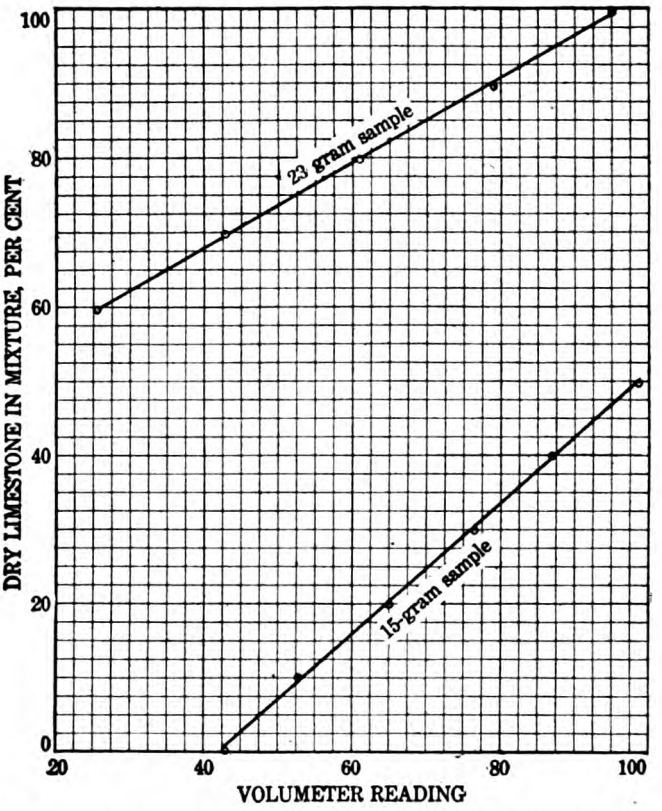


FIGURE 2.—Curves showing relation between readings of Taffanel volumeter and percentages of dry limestone in synthetic mixtures of Pittsburgh coal and limestone dust; series 2 tests.

calibration curves were necessary—one for low-ash mixtures, a 15-gram sample being used, and another for high-ash mixtures, a 20-gram or 23-gram sample being used. In order to avoid this source of trouble the dimensions of the volumeter were modified by increasing the capacity of the graduated part of the measuring tube from 5 c. c. to 10 c. c., the increased capacity being obtained by enlarging the diameter from 7 mm. to 8.6 mm., and lengthening the tube approximately 20 per cent. Detailed dimensions of the new volumeter and of the pipette, and the brass funnel used with it, are given in figure 4.

Generated on 2024-09-28 16:19 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

The volumeter has a capacity of 57 ± 0.1 c. c. to the lowest graduation (100) on the measuring tube. The graduated part of the measuring tube has a total volume of 10 ± 0.05 c. c. and is graduated into 100 divisions. As the zero mark is at the top the volumeter reading increases in direct ratio to the proportion of rock dust or incombustible in the sample. A 20-gram sample will give a scale reading with this apparatus for all mixtures ranging from 100 per cent coal to 100 per cent rock dust. If the pipettes and volumeters are made

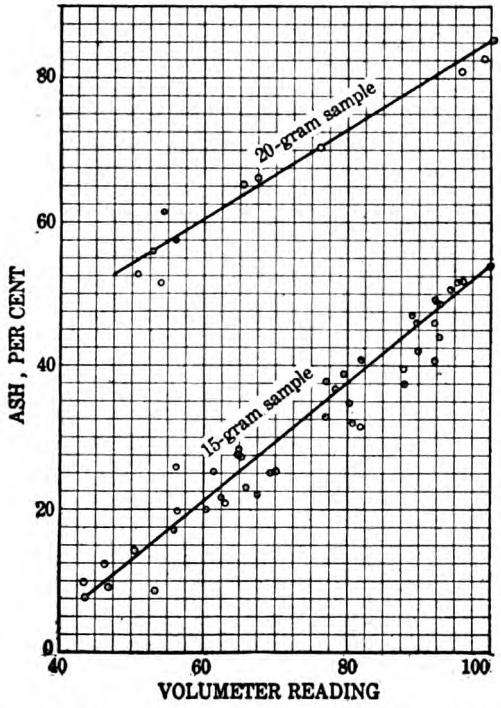


FIGURE 3.—Curves showing relation between readings of Taffanel volumeter and percentages of ash in miscellaneous road and rib dusts from various mines; series 3 tests.

to conform with the specifications indicated in figure 4, the same calibration curve may be used for each outfit. Six outfits made for the Bureau of Mines were found on standardization to give identical results, thus doing away with the necessity of making a new calibration curve when a volumeter or a pipette was broken.

CALIBRATION OF VOLUMETER.

As previously stated, the volumeter is simply an apparatus for determining the volume occupied by a given quantity (20 grams) of dust; this volume is inversely proportional to the density, which is

Generated on 2024-09-28 16:26 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

a linear function of the ash or incombustible content of the mixture. Therefore, if the volumeter readings and the values for the ash or incombustible contents of a series of various mixtures of a given coal

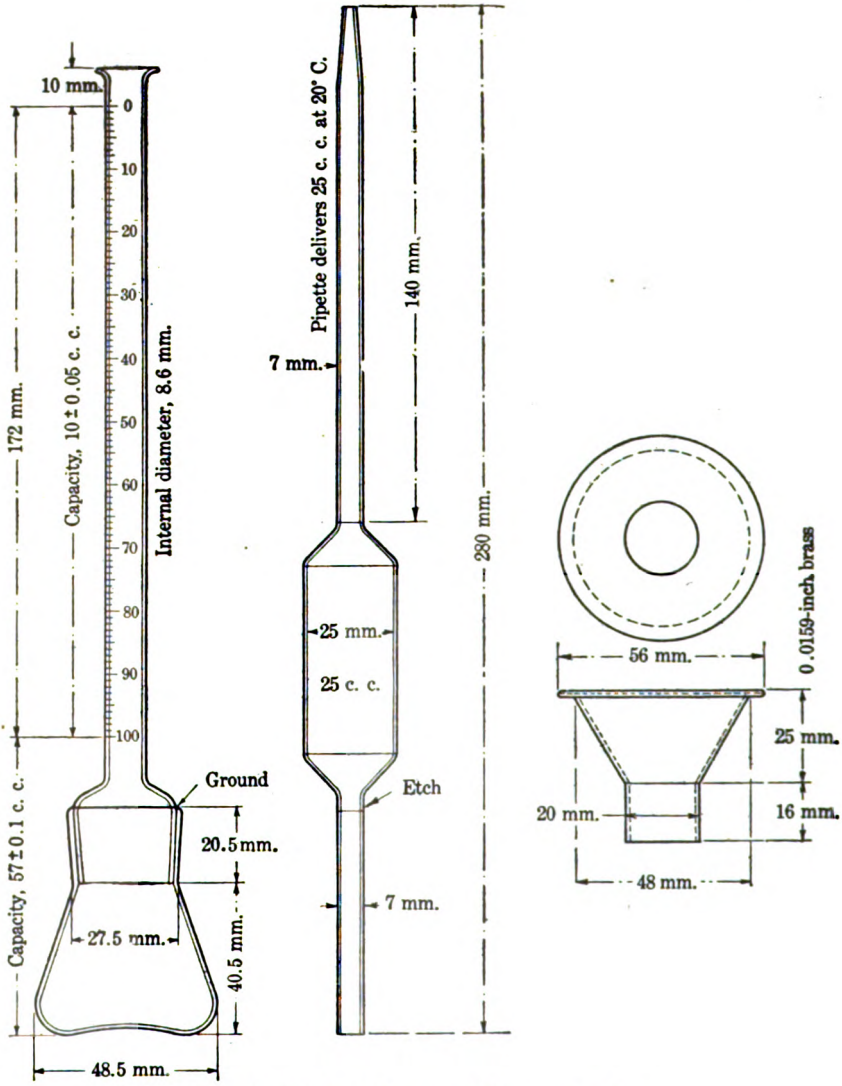


FIG. 4.—Details of Bureau of Mines volumeter.

and rock dust are plotted as abscissas and ordinates, respectively, the points will fall on a straight line, as previously shown in figures 1 and 2. This line is a calibration curve for all possible mixtures of the given coal and rock or for any other coal and rock having the same specific gravity, and the same moisture content. In fact, it is not necessary to prepare mixtures of the two constituents. As two

Generated on 2024-09-28 16:15 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

points are sufficient to establish a straight-line curve, it is necessary merely to make two volumeter determinations, one with 20 grams of the pure coal dust and another with 20 grams of the pure rock dust. A straight line connecting the two points must pass through all points representing mixtures of the two constituents (assuming the same moisture content in all mixtures), as is shown by the equation of the curve, which is derived in the following manner:

Derivation of equation of curve showing relation between volumeter reading and percentage of rock dust in mixtures of coal dust and rock dust.

Let

x=volumeter reading of 20 grams of mixture.
c=volumeter reading of 20 grams of coal dust.
r=volumeter reading of 20 grams of rock dust.
y=percentage of rock dust in the mixture.

Then

$100-y$=percentage of coal dust in the mixture.
67 c. c.=volume of volumeter to 0 mark.
1/10 c. c.=volume of 1 degree volumeter reading.
50 c. c.=volume of alcohol added.

$$67-50-x/10=\frac{170-x}{10}=\text{volume of 20-gram sample of mixture.}$$

Also

$$\frac{170-c}{200} \text{ and } \frac{170-r}{200}=\text{specific volumes of coal and rock dusts.}$$

And

$$\frac{20y}{100}=y/5=\text{grams of rock dust in the mixture.}$$

$$20-y/5=\frac{100-y}{5}=\text{grams of coal dust in the mixture.}$$

Hence, multiplying the weight of each constituent in the mixture by its specific volume, an expression is obtained for the volume of the mixture, which gives the following equation:

$$y/5\ \frac{(170-r)}{200}+\frac{(100-y)}{5}\ \frac{(170-c)}{200}=\frac{170-x}{10}$$

which simplifies as follows:

$$y=\frac{100\ (c-x)}{c-r}=\text{percentage of rock dust in the mixture.} \qquad (1)$$

If y'=percentage of dry rock dust in the mixture and m=percentage of moisture in the rock dust, then $y-my/100=y'$, or $y=100y'/100-m$.

Substituting this value of y in equation *1*,

$$y'=\frac{(c-x)\ (100-m)}{c-r}=\text{percentage of dry rock dust in the mixture.} \qquad (2)$$

The equation for the percentage of ash or dry incombustible in the mixture is derived as follows:

Let

a=percentage of ash or dry incombustible in the coal dust.
b=percentage of ash or dry incombustible in the rock dust.
d=percentage of ash or dry incombustible in the mixture.
y=percentage of rock dust in the mixture.
$100-y$=percentage of coal dust in the mixture.

Generated on 2024-09-28 16:15 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

Then,

$$by/100+a\ (100-y)/100=d \qquad (3)$$

and

$$\frac{y\ (b-a)}{100}+a=d.$$

But from equation *1*, $y=100\ (c-x)/(c-r)$.

Substituting in (*3*),

$(b-a)\ (c-x)/(c-r)+a=d$ percentage of ash or dry incombustible in mixture, or

$d=(b-a)\ (c-x)/(c-r)+a=$percentage of ash or dry incombustible in mixture. (*4*)

EFFECT OF MOISTURE ON VOLUMETER RESULTS.

Equations *2* and *4*, representing percentages of dry rock dust and ash or dry incombustible in dust mixtures, are based on the assumption that the moisture content of each component of the various mixtures remains unchanged. Under practical conditions of rock dusting in mines the moisture will necessarily vary over a considerable range, which must have some effect on the volumeter determinations. This effect comprises (1) contraction in volume of total liquid when alcohol and water are mixed, making a plus error in the volumeter readings, and (2) replacement of a part of the coal dust of approximately 1.30 specific gravity by an equal weight of water of 1.00 specific gravity, making a minus error in the volumeter reading. Fortunately, these two effects are compensating to a certain degree, making a comparatively small total effect on the final result, as shown by the following theoretical calculations:

Calculations covering contraction in volume when alcohol and water are mixed.

Ten per cent moisture in a 20-gram sample of dust corresponds to 2 c. c. of water. Assuming that 50 c. c. of 95 per cent alcohol (by volume) is used in the volumeter determination, the contraction is computed by reference to alcohol tables as follows:

95 per cent alcohol by volume=92.41 per cent by weight, and has a specific gravity of 0.81611.

$50\times0.81611=40.8055$ grams, weight of alcohol.

$40.8055\times0.9241=37.7088$ grams, absolute alcohol in 50 c. c. of 95 per cent alcohol.

$40.8055+1.9981=42.8036$ grams, weight of diluted alcohol.

$37.7088/42.8036\times100=88.10$ per cent alcohol by weight in diluted mixture=91.84 per cent by volume, and 0.82762 specific gravity.

$42.8036/0.82761=51.72$ c. c., total volume of diluted alcohol.

$52-51.72=0.28$ c. c., contraction on mixing 50 c. c. of 95 per cent alcohol and 2 c. c. of water.

In a similar manner the contraction when 4 c. c. of water is added, representing the moisture in 20 grams of dust containing 20 per cent moisture, was calculated to be 0.52 c. c.

Generated on 2024-09-28 16:26 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

These values are for 95 per cent alcohol. If the same alcohol were used repeatedly with dusts containing 5 to 15 per cent moisture, it would become diluted with water from the dust and eventually would have its strength reduced. Hence, calculations were made for alcohols of various degrees of dilution, with results as shown in Table 5 following.

TABLE 5.—*Calculations showing contractions in volumes when 50 c. c. of alcohols of various strengths are mixed with water.*

Strength of alcohol, per cent by volume.	Contraction due to 10 per cent moisture, c. c.	Contraction due to 20 per cent moisture, c. c.	Contraction due to 30 per cent moisture, c. c.
95	0.28	0.52	....
93	.25	.46	....
90	.21	.40	0.57
85	.17	.34	....
80	.15	.29	....

The results show, for alcohols ranging from 95 to 80 per cent strength, diminutions of contraction values of 0.13 and 0.23 c. c. for dusts containing 10 and 20 per cent moisture. As 1 degree on the volumeter has a volume of 0.10 c. c. and corresponds to approximately 1 per cent of incombustible in the mixture, the possible error caused by assuming a constant alcohol strength of 90 per cent would not exceed 1 per cent in samples containing 10 per cent moisture, or 1.5 per cent in samples containing 20 per cent moisture. For determining rock dusts in mines, errors of 1 or 2 per cent may be neglected, and the contraction values for 90 per cent alcohol may be used in correcting calibration curves for the effect of moisture, as follows:

Contraction values for 90 per cent alcohol.

Moisture content of mixture, per cent.	Contraction value, c. c.	Correction to volumeter reading.
10	0.20	−2
20	.40	−4
30	.57	−5.7

The expansion in total volume of a 20-gram sample of dust by the introduction of a given percentage of additional moisture is readily calculated, as follows:

Calculations covering expansion in volume due to replacing coal dust with water.

Let n=percentage of moisture in mixture.

Then $20n/100=n/5$ grams of moisture in sample, which has displaced an equal weight of coal, having a volume of

$$\frac{n/5}{200/(170-c)}.$$

Generated on 2024-09-28 16:15 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

This simplifies to $n(170-c)/1{,}000$, $n/5-n(170-c)/1{,}000=n(30+c)/1{,}000$ c. c., expansion in volume of 20 grams of dust mixture due to water replacing coal dust.

As 1 degree volumeter reading is 1/10 c. c., the correction to be added to the reading will be $[n(30+c)/1{,}000]$ 10, or $n(30+c)/100$.

When the specific gravity of the pure coal dust can not be determined directly with the volumeter, in order to get the value of c the gravity may be taken as 1.30 without causing an error of more than 0.5 per cent in the result.

If 1.30 be assumed as the specific gravity of coal dust, the correction for expansion in volume is calculated as follows:

$n/5$ grams of coal dust is replaced by an equal weight of water.

The volume of the water is $n/5$ c. c.

The volume of the coal dust is $(n/5)/1.30=n/6.50$ c. c.

The increase of volume is $n/5-n/6.50=0.30n/6.50=3n/65$ c. c., and the correction to be added to the volumeter reading is 10 $(3n/65)$ or $6n/13$.

For 10 per cent moisture the correction is:

$(6/13)$ $10=4.6°$ volumeter reading.

For 20 per cent moisture the correction is:

$(6/13)$ $20=9.2°$ volumeter reading.

For 30 per cent moisture the correction is:

$(6/13)$ $30=13.8°$ volumeter reading.

Combining the above plus corrections with the previously determined minus corrections due to contraction of alcohol and water, the total corrections for the effect of moisture are as follows:

Corrections to be made in volumeter reading to offset effect of moisture.

Moisture content of mixture, per cent.	Correction for mixing alcohol and water.	Correction for replacing coal with water.	Total correction.
10	−2.1	+ 4.6	+2.5
20	−4.0	+ 9.2	+5.2
30	−5.7	+13.8	+8.1

RESULTS OBTAINED WITH THE BUREAU OF MINES VOLUMETER.

The Bureau of Mines volumeter was used to make tests with three classes of materials of known ash content. In each test a 20-gram sample and 50 c. c. of alcohol were used. The materials tested were as follows: Series 1 tests, synthetic mixtures of Pittsburgh coal dust and shale; series 2 tests, synthetic mixtures of Pittsburgh coal dust and limestone; and series 3 tests, miscellaneous road dusts from various mines. The results obtained are given in Tables 6, 7, and 8, following, and are indicated in figures 5, 6, and 7, in which the volumeter readings are plotted as abscissas, and the percentages of dry rock dust, dry incombustible, and ash are plotted as ordinates.

Generated on 2024-09-28 16:19 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

TABLE 6.—*Results obtained with Bureau of Mines volumeter in determinations of percentages of dry shale, dry incombustible, and ash in synthetic mixtures of air-dried coal and shale dusts from experimental mine, series 1 tests.*

Mixture.		Volumeter reading.	Calculated percentage in mixture.		
Coal.[a]	Shale.[b]		Dry shale.	Dry incombustible.	Ash.
Grams.	*Grams.*				
100	0	17.0	0.0	6.1	5.8
90	10	26.5	9.9	14.9	14.5
70	30	42.8	29.7	33.5	31.9
50	50	58.5	49.5	51.8	49.3
30	70	74.3	69.2	70.1	66.8
0	100	99.0	98.9	97.5	92.9

[a] Air-dried coal No. 24077, containing 1 per cent moisture and 5.8 per cent ash.
[b] Air-dried shale No. 24156, containing 1.1 per cent moisture and 92.9 per cent ash.

TABLE 7.—*Results obtained with the Bureau of Mines volumeter in determinations of percentages of dry limestone and incombustible (ash+CO_2) in synthetic mixtures of air-dried coal and limestone dusts from the experimental mine, series 2 tests.*

Mixture.		Volumeter reading.	Calculated percentage in mixture.	
Coal.[a]	Limestone.[b]		Dry limestone.	Dry incombustible.
Grams.	*Grams.*			
100	0	22.0	0.0	9.4
90	10	29.8	10.0	18.4
70	30	44.0	30.0	36.3
50	50	59.5	50.0	54.4
30	70	76.3	69.9	72.4
0	100	98.3	99.9	99.4

[a] Air-dried coal No. 21449, containing 1.1 per cent moisture and 9.4 per cent ash.
[b] Air-dried limestone No. 19096, containing 0.2 per cent moisture and 99.4 per cent (ash + CO_2).

TABLE 8.—*Results obtained with Bureau of Mines volumeter in determining percentages of ash in air-dried road dusts from various mines.*

Laboratory No.	Description and source of sample.	Moisture in dust—		Volumeter reading.	Ash by—		Difference.
		As received.	Air dried.		Volumeter.	Incineration.	
		Per cent.	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
22403	Bituminous coal, Sewanee bed, Grundy County, Tenn	4.5	1.9	22.8	9.5	7.9	+1.6
22437	Road dust, Upper Kittanning bed, Cambria County, Pa	4.5	1.3	29.5	16.5	15.9	+ .6
24867	Road dust, No. 2 bed, Vigo County, Ind	9.7	4.3	30.3	17.3	17.7	− .4
24719	Road dust, Harlan bed, Harlan County, Ky.	8.7	1.3	34.0	21.5	19.4	+2.1
24733	.....do	9.9	1.3	47.5	35.5	34.7	+ .8
24774	.....do	6.9	1.8	41.3	29.0	30.0	−1.0
24224	Road dust, Crawford County, Kans	6.8	1.5	44.8	32.5	34.0	−1.5
24219	.....do	10.4	1.7	54.3	43.0	45.7	−2.7
22720	Road dust, No. 6 bed, Montgomery County, Ill	6.3	4.7	56.0	44.5	43.8	+ .7
21869	Road dust, No. 5 bed, Vigo County, Ind	14.0	6.9	64.0	53.0	43.8	[a]+9.2
24514	Road dust, Mary Lee bed, Jefferson County, Ky	8.9	.7	55.3	44.0	51.4	−7.4
21497	Road dust, Pittsburgh bed, Allegheny County, Pa	8.1	2.9	66.5	56.0	55.1	+ .9

[a] This dust contained considerable pyrite.

Generated on 2024-09-28 16:15 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

The percentages of dry incombustible in the shale and in the miscellaneous road dusts are calculated by multiplying the percentage of ash, obtained by incineration, by the factor 1.05, an average correction for combined water in hydrous silicates; the percentage of dry incombustible in limestone is the sum of the percentage of ash, ob-

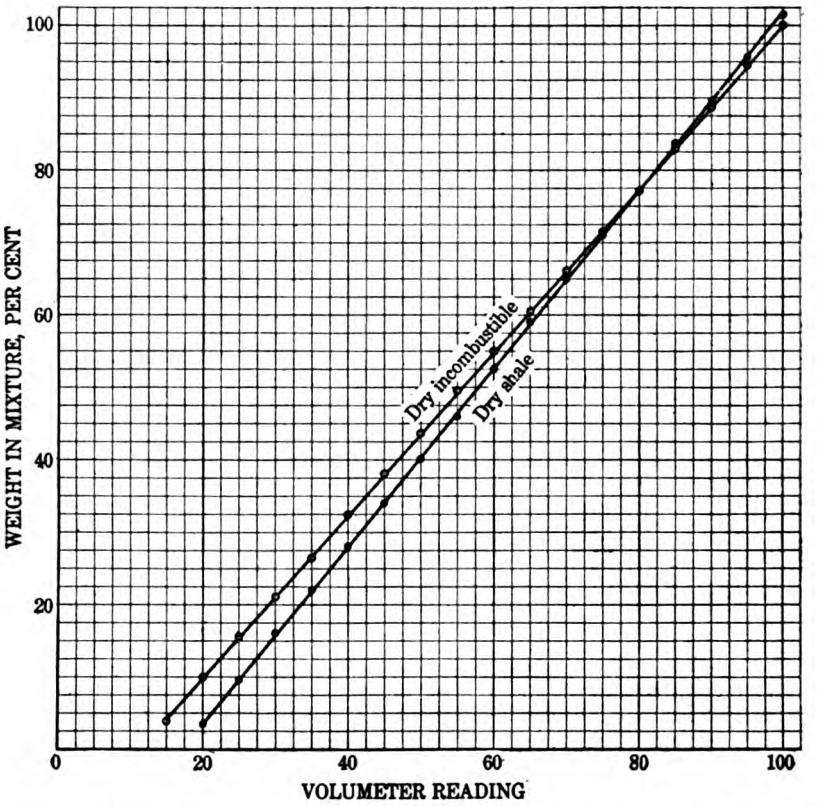


FIGURE 5.—Curves showing relation between readings of Bureau of Mines volumeter and percentages of dry shale, dry incombustible, and ash in air-dried mixtures of Pittsburgh coal and shale dust from experimental mine, series 1 tests.

tained by incineration at 900° C., and the percentage of carbon dioxide, obtained by evolution with acid.

Figures 5 and 6 indicate that all the points fall on a straight line, again showing that in various mixtures of a given coal dust and a given rock dust, of approximately constant moisture content, the volumeter is capable of results accurate to 1 per cent. The accuracy is, of course, less when the instrument is used with miscellaneous coal dusts and rock dusts from various mines, as is shown in Table 8 and in figure 7. In the determinations there represented the maximum deviation of the volumeter result from the true ash was 9.2 per cent, although 10 out of 12 results were within 3 per cent.

Generated on 2024-09-28 16:15 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

Table 9 following contains a comparison of the volumeter readings in terms of percentage of incombustible as read from the calibration curves of figures 5, 6, and 7, representing mixtures of shale and coal, of limestone and coal, and of miscellaneous road dusts. It will be noted that the values are closely similar, the greatest difference being 3.5 per cent in the values for limestone samples and those for miscellaneous road-dust samples.

TABLE 9.—*Results obtained with Bureau of Mines volumeter in determinations of percentages of dry incombustible (ash+CO_2) in samples of air-dried road and rib dusts taken in Gallatin mine after rock dusting with limestone.*

[Volumeter readings referred to coal and limestone curve in fig. 6, p. 22.]

Laboratory No	Description of sample.	Moisture in sample—		Volumeter reading.	Proportion of ash +CO_2 by—		Difference.
		As received.	Air dried.		Volumeter.	Analysis.[a]	
		Per cent.	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
24662	Road dust	3.3	1.3	35.5	25.0	25.2	−0.2
24295	do	11.6	1.5	36.5	26.0	27.1	−1.1
24292	do	9.6	2.8	39.5	29.5	29.2	+ .3
24760	do	8.7	3.3	43.0	33.5	33.1	+ .4
24294	do	3.6	1.1	42.5	33.0	35.1	−2.1
24661	do	3.3	1.3	48.3	40.0	41.5	−1.5
24132	do	4.8	1.1	53.5	46.0	47.1	−1.1
23722	do	2.3	1.2	57.5	50.5	52.6	−2.1
23714	do	2.5	1.1	67.8	63.0	63.4	− .4
24759	do	2.8	.8	74.0	70.0	71.7	−1.7
24668	Rib dust	.6	.4	96.3	96.0	97.1	−1.1
24667	do	1.1	.4	95.5	96.5	96.8	− .3
21234	Floor dust	6.7	1.3	80.5	77.5	78.2	− .7
23180	Road dust	7.8	1.3	59.3	53.0	52.9	+ .1
23428	do	1.6	1.0	66.8	61.5	63.5	−2.0

[a] Ash determined by incineration at 900° C.; CO_2 determined by evolution with acid.

The accuracy obtainable in the practical use of the volumeter in determining the percentage of dry incombustible in the road and rib dusts of a mine in which rock dusting is being practiced is indicated by the results presented in Table 9. During the past two years the Bureau of Mines has been carrying on rock-dusting experiments in the Gallatin mine of the Monongahela River Consolidated Coal & Coke Co. at Gallatin, Pa., limestone dust being used. At regular intervals samples of the road and rib dusts were taken by engineers of the bureau and sent to the bureau's laboratory for analysis. After the samples had been air-dried, the ash content of each was determed by incineration at 900° C., and the carbon dioxide from the limestone was determined by evolution with acid. The dry incombustible was taken as the sum of the ash and the carbon dioxide. A number of the air-dried samples were also subjected to volumeter determinations and the percentage of dry incombustible was read from the calibration curve given in figure 6, this curve having been constructed from determinations on synthetic mixtures of Pittsburgh coal dust and limestone dust. Table 9 indicates that the largest error

Generated on 2024-09-28 16:33 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

in the volumeter result was only 2.1 per cent, which may be regarded as entirely negligible as regards the use of the volumeter for determining the composition of rock-dust mixtures in mines.

EFFECT OF VARIABLE MOISTURE CONTENT.

All of the calibration curves previously mentioned were plotted from results with air-dried samples. In the practical use of the volumeter the tests must generally be made on the sample in the

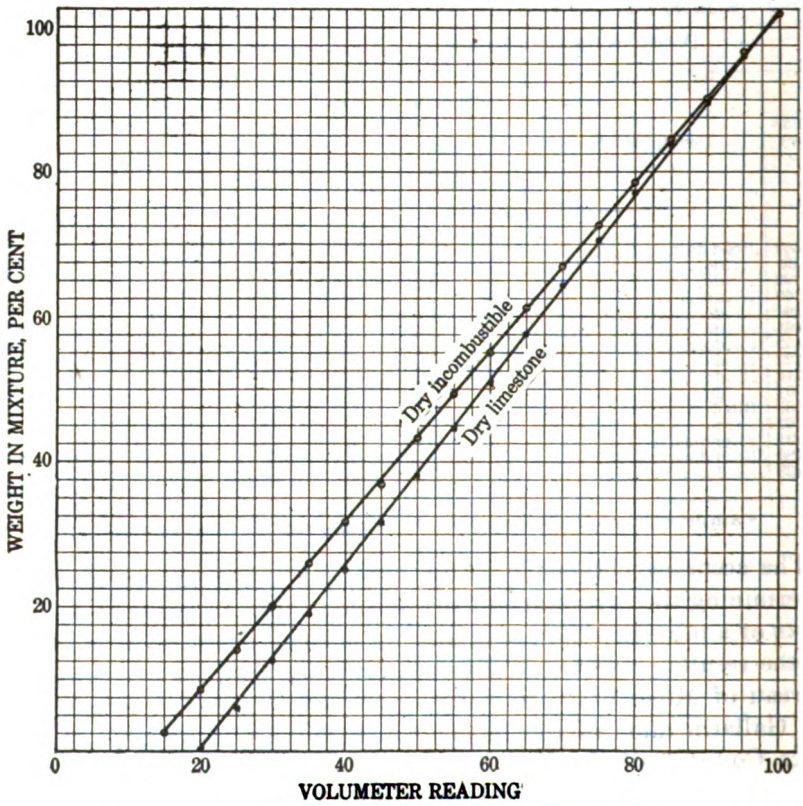


FIGURE 6.—Curves showing relation between readings of Bureau of Mines volumeter and percentages of dry limestone and dry incombustible in air-dried mixtures of Pittsburgh coal and limestone dust from the experimental mine, series 2 tests.

condition as taken in the mine. As shown in Table 9, the samples taken in the Gallatin mine before being air-dried contained 0.6 to 11.6 per cent total moisture. Corrections had to be made for the effect of this range of moisture variation on the accuracy of the volumeter results. It has been shown that theoretically the effect of 10 per cent added water can be corrected by adding 2.5 to the volumeter reading, and likewise the effect of 20 per cent added water is corrected by

Generated on 2024-09-28 16:15 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

adding 5.2 to the volumeter reading. In order to test the accuracy of the procedure mentioned, actual experiments were made in which various percentages of water were added to samples of coal, shale, limestone mixtures, and road dusts containing various percentages of combustible. The results are given in Table 10 following:

TABLE 10.—*Results of experiments to determine influence of moisture on volumeter reading.*

[20-gram samples used.]

Moisture added.	Water added.	Weight of sample.	Description of sample.	Sample No.	Volumeter reading.	Theoretical correction to volumeter reading for added moisture.[a]	Corrected volumeter reading.	Incombustible shown by corrected volumeter reading.[b]	Incombustible shown by analysis.	Difference or error.
P. ct.	*Grams.*	*Grams.*						*P. ct.*	*P. ct.*	
10	2	18	Air-dried coal.....	24077	16.5	2.5	19.0	7.5	5.5	+2.0
10	2	18	Air-dried shale.....	24156	88.8	2.5	91.3	88.5	87.8	+ .7
10	2	18	Air-dried coal.....	21449	20.0	2.5	22.5	10.0	8.4	+1.6
10	2	18	Air-dried limestone....	19095	88.0	2.5	90.5	89.5	89.9	− .4
10	2	18	Air-dried road dust....	22403	20.0	2.5	22.5	9.5	7.1	+2.4
10	2	18	.....do.....	24867	25.5	2.5	28.0	15.5	15.9	− .4
10	2	18	.....do.....	24744	36.0	2.5	38.5	27.0	27.0	.0
10	2	18	.....do.....	24219	47.8	2.5	50.3	40.5	41.1	− .6
10	2	18	.....do.....	[c]24662	30.3	2.5	32.8	22.0	22.7	− .7
10	2	18	.....do.....	[c]24132	47.8	2.5	50.3	42.0	42.4	− .4
10	2	18	.....do.....	[c]24759	66.0	2.5	68.5	63.5	64.5	−1.0
20	4	16	Air-dried coal.....	24077	12.8	5.2	18.0	6.0	4.9	+1.1
20	4	16	Air-dried shale.....	24156	76.0	5.2	81.2	77.0	78.0	−1.0

[a] See table on page 18.
[b] Calibration curves of figures 5, 6, and 7 are used.
[c] Containing limestone, Gallatin mine.

The table shows that the calculated effect of 10 or 20 per cent moisture agrees with that determined by experiment to within about 1 per cent for all mixtures containing more than 10 per cent incombustible. For pure coal dusts the calculated correction is seemingly too large by about 1.5. However, this difference is not important, as the volumeter method is not used for such materials.

It may be assumed that the maximum change in volumeter reading that would be caused in the Gallatin-mine samples by using samples of coal as received in place of air-dried samples would be 2.5. This corresponds to a possible maximum error of 2.5 per cent of incombustible if the calibration curve for air-dried coal is used. Obviously this error may be reduced one-half by applying a plus correction of 1.2 to the volumeter readings and using the curve for air-dried coal, or by drawing a curve to include this correction, which is to be used for all samples of material as received that contain 0 to 10 per cent moisture above that retained in the air-dried material. This calibration curve would cover the range of moisture found in the Gallatin-mine samples, with a maximum error of 1.5 per cent combustible

Generated on 2024-09-28 16:15 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

due to moisture variation. This error combined with the maximum volumeter error of 2.0 per cent in the results shown in Table 9 would make the total maximum error in the practical use of the volumeter for undried samples as taken in the mine approximately 3.5 per cent.

Tables 4 and 8 show that in 64 samples of road dusts from various mines, the total percentage of moisture in material as received exceeded the percentage of moisture in the air-dried samples by 10 per cent in only one sample—a North Dakota lignite. Hence a similar mean calibration curve for miscellaneous road dusts may be con-

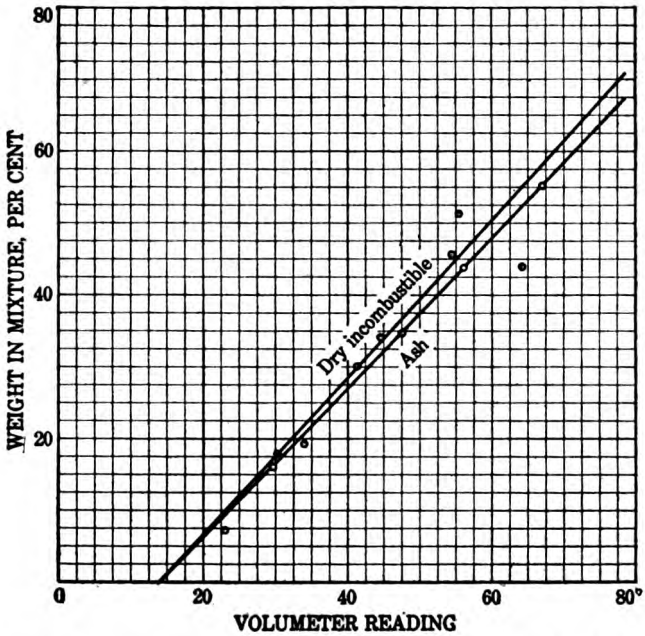


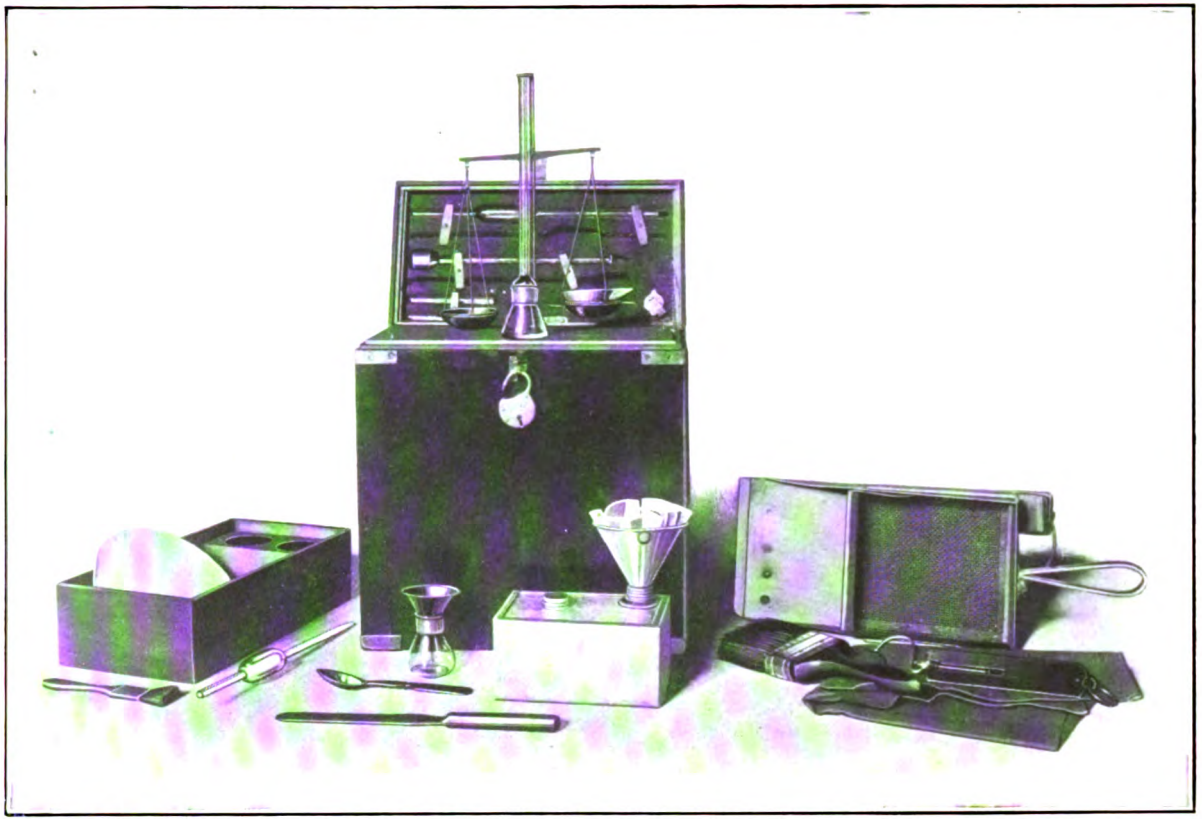
FIGURE 7.—Curves showing relation between readings of Bureau of Mines volumeter and percentages of dry incombustible and ash in air-dried road and coal dusts from various mines, series 3 tests.

structed for samples containing 5 per cent water in addition to that contained in the air-dried samples by adding a correction of 1.2 to the volumeter reading used with the curve for air-dried samples. With this correction the volumeter results for miscellaneous undried road dusts will have an average probable error of less than 5 per cent, and a maximum error for occasional samples of approximately 11 per cent.

The corrected data for calibration curves for the Bureau of Mines volumeter when used with undried or "as-received" samples are given in Table 11 following.

Generated on 2024-09-28 16:16 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

Generated on 2024-09-28 16:17 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google



VOLUMETER AND CARRYING CASE.

Digitized by Google
Original from PRINCETON UNIVERSITY

TABLE 11.—*Data for calibration curves for Bureau of Mines volumeter for use with undried or "as-received" mixtures of Pittsburgh coal dust and shale dust, Pittsburgh coal dust and limestone dust, and miscellaneous road dusts.*

Volumeter reading.	Percentage of dry incombustible in mixture.			Percentage of dry rock dust in mixture.	
	Coal [a] and shale.	Coal [b] and limestone.	Miscellaneous road dusts.[a]	Coal and shale.	Coal and limestone.
15	4.0	2.5	2.5	0.0	0.0
20	10.0	8.5	8.0	3.5	0.0
25	15.5	14.0	13.5	9.5	6.0
30	21.0	20.0	19.0	16.0	12.5
35	26.5	26.0	25.0	22.0	19.0
40	32.5	31.5	30.5	28.0	25.0
45	38.0	36.0	36.0	34.0	31.5
50	43.5	43.5	41.5	40.0	38.0
55	49.5	49.0	47.0	46.0	44.5
60	55.0	55.0	52.5	52.5	51.0
65	60.5	61.0	58.5	59.0	57.5
70	66.0	67.0	64.0	65.0	64.5
75	71.5	72.5	69.5	71.0	70.5
80	77.0	78.5	75.0	77.0	77.0
85	83.0	84.5	81.0	83.5	83.5
90	88.5	90.0	86.5	89.5	89.5
95	94.5	96.5	92.0	95.5	96.5
100	100.0	101.5	98.0	101.5	102.5

[a] Dry incombustible=1.05 times ash.
[b] Dry incombustible=ash+CO_2.

DESCRIPTION OF PORTABLE OUTFIT.

The complete portable outfit for use at a mine for collecting samples of road and rib dusts and determining the percentage of rock dust or dry incombustible is contained in the carrying case shown in Plate I. Its weight, including one quart of alcohol, is approximately 20 pounds. The wood-carrying case is made of poplar three-eighths of an inch thick, dovetailed at the corners, and brass bound. It is provided with a hinged cover, and a handle for carrying. The outside dimensions are 7 by 13 inches by 14 inches high, which furnish ample room for all the required apparatus, cans of alcohol, extra sample containers, etc.

In the cover are felt-lined recesses in which are fitted the glass parts of the outfit, pipettes, volumeter tubes, and test tubes. The volumeter flasks are packed in felt-lined compartments contained in a tray 3 inches deep which fits into the upper part of the box. This tray also contains the balance, weights, scoop, brush, and other light articles. The heavier articles used in collecting the sample in the mine and the can of alcohol are packed in the space under the tray. On the top of the tray is fitted a thin board which prevents the articles in the tray from coming in contact with the glass parts in the cover during transportation, thus preventing breakage. This thin board also serves for a work table on which the balance is set up and the weighings are made (see Pl. I).

The complete outfit is shown in Plate I, with the balance set up for use. The removable tray is shown to the left of the case, and

Generated on 2024-09-28 16:19 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

the 10-mesh scoop, brush, spring balance, and rubber cloth for collecting samples in the mine are shown on the right. The articles included in the outfit are enumerated in the list following:

EQUIPMENT INCLUDED IN PORTABLE OUTFIT.

Articles That Are Kept in Stock by Laboratory Supply Houses.

One horn spoon, 5 inches long.
One doublet magnifier; magnification 14 times.
Two ½-inch by 4-inch test tubes.
One weighing spatula with 4-inch tapering blade, and wood handle.
One flexible steel spatula with wood handle and 6-inch blade.
One hand balance with 6-inch polished-brass beam, steel knife edges, 2½-inch horn pans, and silk cord.
One aluminum weighing scoop and counterweight.
One 20-gram brass weight.
One flat camel's hair brush for cleaning scale pans; ½ inch wide.
One package of 18-centimeter filter paper of the quality ordinarily used in qualitative analysis.

Articles Obtained From Other Sources or Made to Order.

One wood carrying case, 7 by 13 by 14 inches, outside dimensions, to be made by carpenter or trunk maker.
Two Bureau of Mines volumeters, two pipettes, and one brass funnel, made according to figure 4, by chemical-laboratory supply house.
One piece of $\frac{3}{16}$-inch iron wire, 15 inches long, bent to form balance support.
One 3½-inch tin funnel. Sold by hardware stores.
One or two tin or galvanized-iron alcohol cans of 1-quart capacity. Sold by hardware stores or made by tinner.
One 3-inch flat brush. Sold by hardware stores.
One special galvanized-iron scoop fitted with 10-mesh sieve. Made by tinner.
One spring balance, 50-pound capacity. Sold by hardware stores.

METHOD OF MAKING VOLUMETER DETERMINATIONS.

The outfit can be quickly prepared for making volumeter determinations by opening the cover and removing the tray and its cover board and the other articles in the bottom of the box. The wire balance support is then removed from the cover board of the tray, and this board is inverted and placed back in the top of the box to serve as a weighing table. The wire support is inserted in an opening in the rear of the box and the balance is suspended on the support. The outfit will now be in the position shown in Plate I.

The aluminum scoop is placed on one side and the counterpoise on the other. A test swing of the balance should be made to indicate whether the pointer swings to the same distance on either side; if not, it should be adjusted to swing equally on both sides. The

Generated on 2024-09-28 16:25 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

20-gram weight should be placed on the same side as the counterpoise, and successive spoonfuls of the sample should be placed in the aluminum scoop until the balance again swings an equal distance on each side of the center.

The sample should all pass through a 10-mesh screen. Before it is weighed, it should be thoroughly mixed on the rubber cloth by successively lifting opposite corners of the cloth and rolling the sample in all directions. The large spatula may be used to aid this mixing process. After the mixing operation, the sample is spread in a smooth layer with the spatula, and the sample for weighing is then transferred to the aluminum scoop on the balance pan by taking spoonfuls of the material at various places so as to get a fair average of the entire sample.

The volumeter flask, with the measuring tube removed, is placed in position in the clips provided on the board in front of the balance. The flask, especially the ground joint for the measuring tube, should be wiped perfectly clean and dry with a cloth before it is used. The flask funnel is inserted and the 20-gram sample of road dust is brushed into it from the aluminum weighing scoop. Care must be observed that none of the sample is spilled during this transfer. After any material adhering to the funnel has been brushed into the flask, the funnel is removed and 25 c. c. of alcohol from a pipette is allowed to run into the flask. The pipette is filled with alcohol by inserting the pointed end in the alcohol can and applying suction with the mouth at the other end until the level of the alcohol is well above the ring etched on the stem above the bulb. The operator then removes the pipette from his mouth and places his finger tip quickly over the opening before the alcohol level can flow below the etched ring. While holding his finger tightly over the pipette, the operator removes the pipette from the can and by suitable manipulation of his finger allows the alcohol to flow out slowly until the bottom of the meniscus, the convex downward boundary surface between the alcohol and the air, just reaches the etched ring above the bulb. He then inserts the tip of the pipette in the flask and by removing his finger entirely from the top of the pipette allows the alcohol to flow into the flask. As soon as the free-running stream has stopped, the tip of the pipette is touched to the side of the flask, and the adhering drop of alcohol is blown out at once, and the pipette is removed before any more alcohol can drain down. In using the pipette care must be taken that it is filled to the mark and that no alcohol is lost while the pipette is being transferred from the can to the flask.

The measuring tube is next inserted in the flask, and the volumeter is gently shaken to impregnate the sample thoroughly with the alcohol and to allow the air bubbles to escape. As two volumeters are

Generated on 2024-09-28 16:24 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

usually included in each outfit, care must be observed to use the proper measuring tube. A number is etched on the neck of each flask, and the measuring tube used with a given flask must have the same number etched on it; otherwise the results will be erroneous.

After the volumeter has been shaken, a second 25 c. c. volume of alcohol from the pipette is introduced in the apparatus at the top of the measuring tube. After the mixture has stood for 30 seconds, the reading of the bottom of the meniscus is taken on the measuring tube, and by reference to the calibration table or curve the percentage of incombustible or of rock dust in the sample is ascertained.

The alcohol may be recovered and used repeatedly. It is recovered by placing a filter paper in the tin funnel and inserting the funnel in the alcohol can. The volumeter is placed over the funnel, the measuring tube is lifted out, the flask is inverted over the funnel, and the solution of alcohol and dust poured off. The solid matter in the alcohol is removed by the filter. The residue remaining in the flask is washed out with water. The flask and measuring tube are then wiped dry with a cloth. It is advisable to make determinations with the same sample until the operator is certain that his manipulations are correct. Duplicate determinations should not vary more than one or two divisions on the instrument.

METHOD OF CALIBRATING VOLUMETER.

The calibration curves for the Bureau of Mines form of volumeter are given in figures 8, 9, and 10. Figure 8 is the curve for "as-received" or undried mixtures of Pittsburgh coal and shale such as are being used in the rock-dusting experiments at the bureau's experimental mine. The average probable error in using this curve for mixtures containing not more than 10 per cent moisture in excess of that contained in the air-dried material is 2 per cent. The maximum error should not exceed 4 per cent.

Figure 9 is a similar curve for "as-received" mixtures of Pittsburgh coal and limestone as used in the rock-dusting tests at the experimental mine of the bureau and at several commercial mines in the Pittsburgh district. The probable errors are of the same magnitude as in curve 8.

Figure 10 is a mean curve for "as-received" road and rib dusts as collected in a number of mines in the United States. The accuracy of the results read from this curve are necessarily less than those obtained from curves especially prepared for definite mixtures of the same coal and rock dust. The probable error may be taken as 5 per cent for most dusts, although occasional errors of 10 per cent may occur when the sample contains much pyrite or other impurities that

Generated on 2024-09-28 16:17 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

have a specific gravity considerably higher or lower than that of shale or limestone.

A special calibration for a given mine where rock dusting is practiced is made in the following manner: Representative samples of the pure rock dust and pure coal dust are prepared, and from these samples, mixtures of coal dust and rock dust in the proportions of 25, 50, and 75 per cent of rock dust are made. Volumeter determinations are made on each of these mixtures and on the samples of pure

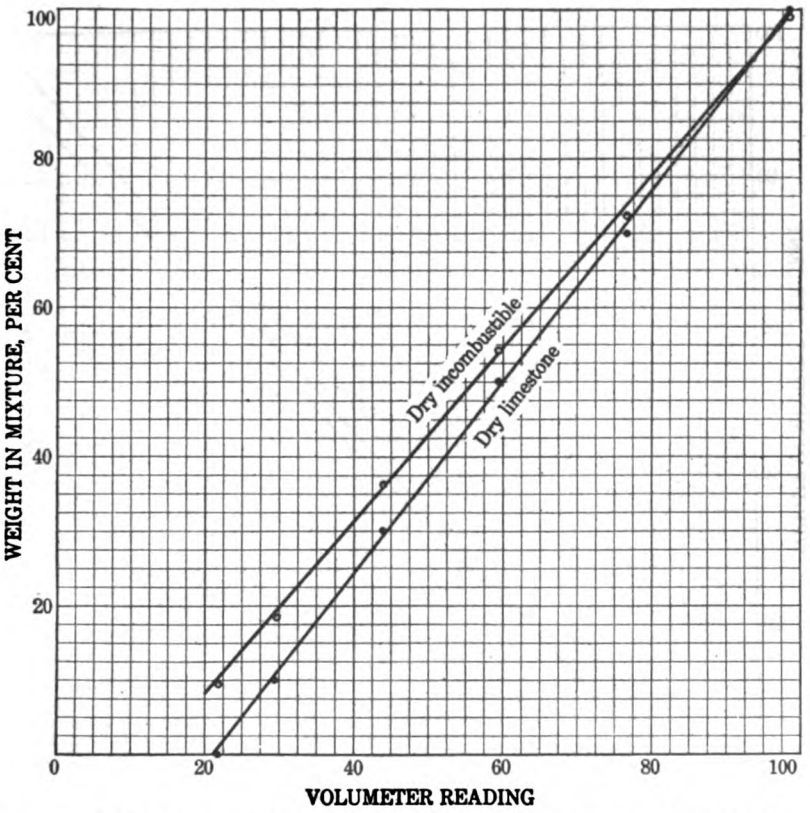


FIGURE 8.—Calibration curve for undried or "as-received" mixtures of Pittsburgh coal and shale dusts used at the experimental mine of the Bureau of Mines.

rock dust and pure coal dust. The volumeter readings are plotted on coordinate paper as abscissas and the percentages of rock dust in the mixture are plotted as ordinates. A straight line drawn through these points is a calibration curve giving the percentages of rock dust (as received) in the mixture. From the same volumeter readings, a curve representing dry rock dust in the mixture may be constructed by determining the moisture in the sample of pure rock dust and calculating the percentages of dry rock dust in each of the synthetic mixtures.

Generated on 2024-09-28 16:16 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

Similarly, the percentage of dry incombustible in each of the calibrating mixtures can be calculated and plotted as ordinates after the dry incombustible matter in the pure coal and in pure rock dust have been determined by the usual chemical methods. As these curves are straight lines, it is theoretically sufficient to establish only two points, such as would be obtained by making volumeter determinations of the pure coal dust and the pure rock dust. Practically, it is better to establish several points, as described above, in order to eliminate possible errors in the individual determinations.

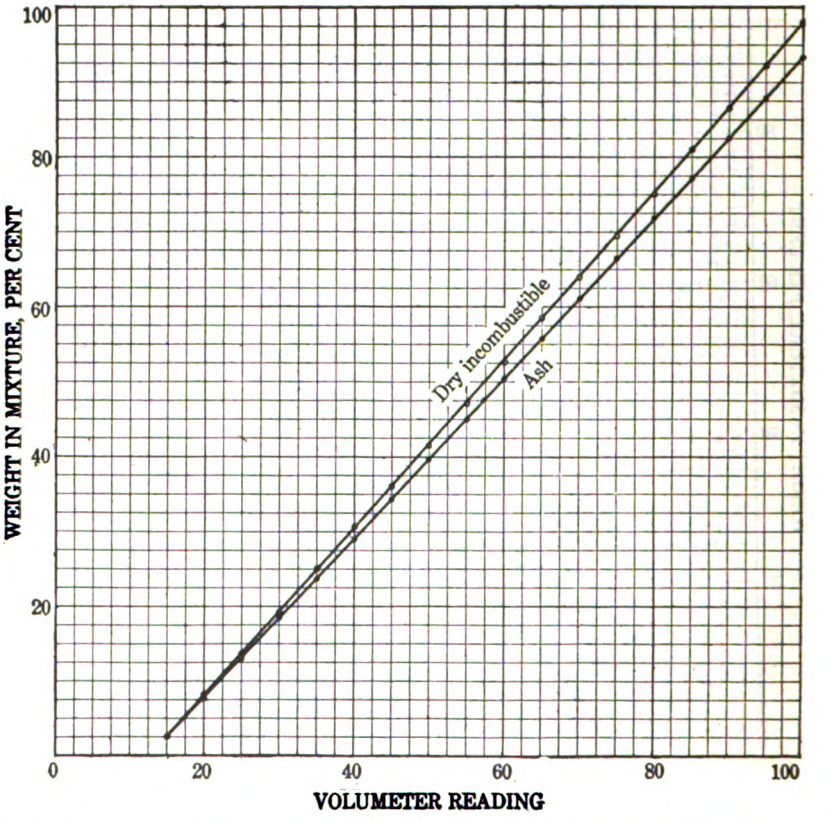


FIGURE 9.—Calibration curve for undried or "as-received" mixtures of Pittsburgh coal dusts and limestone dusts used at the experimental mine of the Bureau of Mines.

DETERMINATION OF SPECIFIC GRAVITY OF COAL AND ROCKS WITH VOLUMETER.

As the volumeter is simply a modified specific-gravity flask, the approximate specific gravity of any coal or rock may be readily calculated from the volumeter reading by the following formula:

$$\frac{200}{170-x}=\text{specific gravity}$$

in which x=volumeter reading.

Generated on 2024-09-28 16:15 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

QUALITATIVE TEST FOR COKED DUST.

In the investigation of mine explosions, it is frequently desired to determine whether globules or hollow bubbles of coke or fused material from the partial distillation of coal are present in the dust from the entries and rooms of a mine. Valuable information on the extent and direction of the inflammable wave can be obtained in this manner. A simple test for the presence of coke bubbles is to place 0.2 or 0.3 gram of dust in a test tube containing alcohol, and shake the tube. When the tube has stood a few minutes the coal and rock

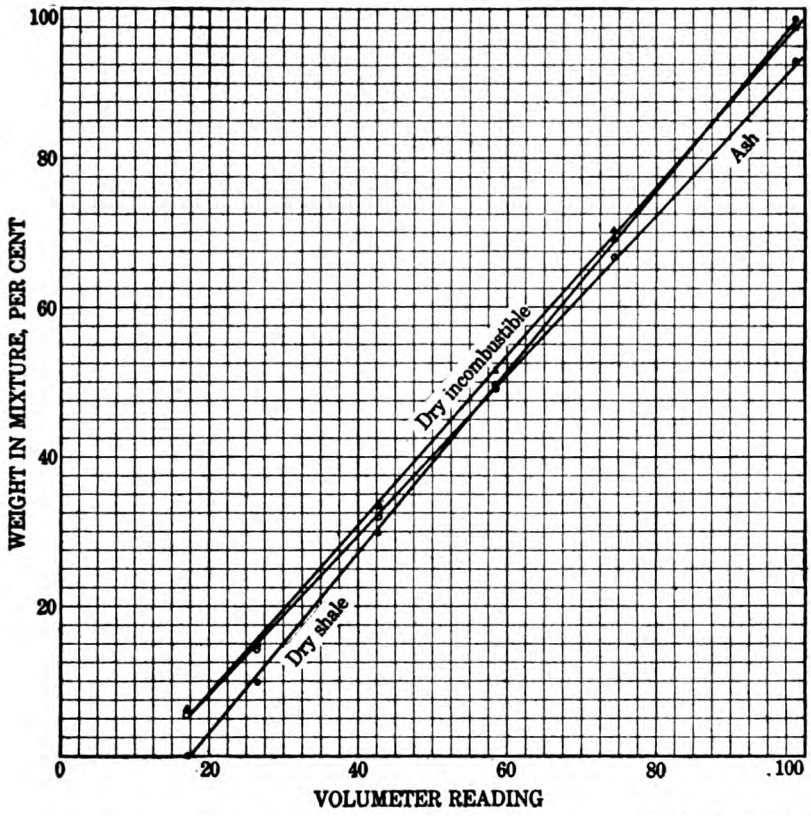


FIGURE 10.—Calibration curve for undried or "as-received" road and rib dusts from various mines.

particles sink to the bottom, while the coke bubbles remain floating on the surface of the alcohol. The floating material is removed, placed on a white surface, as a piece of filter paper, and examined with a magnifying glass. The coked material is recognized by its globular or fused character. Usually there will be seen small hollow bubbles or fragments of bubbles containing translucent yellow spots

Generated on 2024-09-28 16:15 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

at points where the shell of the bubble is very thin. The portable outfit shown in Plate I contains two test tubes and a pocket magnifier for making this test in the field.

SUMMARY.

An investigation of the specific gravity method of determining the percentage of rock dust, ash, or dry incombustible in mixtures of coal and rock dust such as are found in the entries and rooms of mines showed that this method was rapid and sufficiently accurate for use in controlling the application of rock dust in mines.

The graduated measuring tube of the original Taffanel volumeter was not long enough to accommodate the entire range of incombustible from zero to 100 per cent, thus necessitating a double calibration with two different weights of sample. Consequently, a new form of volumeter that had ample scale capacity for all percentages of incombustible was designed by chemists of the Bureau of Mines for use with a 20-gram sample.

With synthetic mixtures of air-dried coal and shale, the greatest difference between the percentage incombustible by the volumeter and that by chemical analysis was 1 per cent. The same degree of accuracy was found with air-dried mixtures of coal and limestone.

In a series of miscellaneous air-dried road dusts from various mines, the average error in the percentage of ash indicated by the volumeter was 3 per cent, and the largest error, 9.2 per cent.

The addition of water to the air-dried samples required the following corrections to the volumeter reading:

Corrections to volumeter reading when water is added to sample.

10 per cent water added	+2.5
20 per cent water added	+5.2
30 per cent water added	+8.1

As practically all samples of road and rib dusts in mines (except lignite mines) contain less than 12 per cent of water, in addition to that contained as moisture in the air-dried sample, an average correction of +1.2 may be applied to the volumeter reading of the calibration curves established from readings for air-dried samples. These corrected curves are to be used when undried samples are tested at the mine.

The average probable error in using the volumeter on undried or "as-received" samples of mixtures of coal dust and shale dust, or of limestone dust, is 2 per cent, and the maximum error is 3.5 per cent, the appropriate calibration curve being used for each material in the rock-dust mixture.

Generated on 2024-09-28 16:21 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

The average probable error in using the volumeter with undried or "as-received" road dusts from various mines is 5 per cent, and the maximum error in some samples may reach 11 per cent.

ACKNOWLEDGMENTS.

The authors take pleasure in acknowledging their indebtedness to George S. Rice, chief mining engineer of the Bureau of Mines, who suggested this investigation, and to L. M. Jones, mining engineer, and Edward H. Denny, junior mining engineer, for valuable suggestions in designing the portable apparatus.

Generated on 2024-09-28 16:17 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

PUBLICATIONS ON THE UTILIZATION OF COAL AND LIGNITE.

A limited supply of the following publications of the Bureau of Mines has been printed and is available for free distribution until the edition is exhausted. Requests for all publications can not be granted, and to insure equitable distribution applicants are requested to limit their selection to publications that may be of especial interest to them. Requests for publications should be addressed to the Director, Bureau of Mines.

The Bureau of Mines issues a list showing all its publications available for free distribution as well as those obtainable only from the Superintendent of Documents, Government Printing Office, on payment of the price of printing. Interested persons should apply to the Director, Bureau of Mines, for a copy of the latest list.

PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

BULLETIN 5. Washing and coking tests of coal at the fuel-testing plant, Denver, Colo., July 1, 1908, to June 30, 1909, by A. W. Belden, G. R. Delamater, J. W. Groves, and K. M. Way. 1910. 62 pp., 1 fig.

BULLETIN 6. Coals available for the manufacture of illuminating gas, by A. H. White and Perry Barker, compiled and revised by H. M. Wilson. 1911. 77 pp., 4 pls., 12 figs.

BULLETIN 24. Binders for coal briquets, by J. E. Mills. 56 pp., 1 fig.

BULLETIN 36. Alaskan coal problems, by W. L. Fisher. 1911. 32 pp., 1 pl.

BULLETIN 55. The commercial trend of the producer-gas power plant, by R. H. Fernald. 1913. 93 pp., 1 pl., 4 figs.

BULLETIN 58. Fuel-briquetting investigations, July, 1904, to July, 1912, by C. A. Wright. 1913. 277 pp., 21 pls., 3 figs.

BULLETIN 76. United States coals available for export trade, by Van H. Manning. 1914. 15 pp., 1 pl.

BULLETIN 85. Analyses of mine and car samples of coal collected in the fiscal years 1911 to 1913, by A. C. Fieldner, H. I. Smith, A. H. Fay, and Samuel Sanford. 1914. 444 pp., 2 figs.

BULLETIN 89. Economic methods of utilizing western lignites, by E. J. Babcock. 1915. 74 pp., 5 pls., 5 figs.

BULLETIN 119. Analyses of coals purchased by the Government during the fiscal years 1908–1915, by G. S. Pope. 1916. 118 pp.

BULLETIN 135. Combustion of coal and design of furnaces, by Henry Kreisinger, C. E. Augustine, and F. K. Ovitz. 1917. 140 pp., 1 pl., 45 figs.

BULLETIN 136. Deterioration in the heating value of coal during storage, by H. C. Porter and F. K. Ovitz. 1917. 38 pp., 7 pls.

BULLETIN 138. Coking of Illinois coals, by F. K. Ovitz. 1917. 71 pp., 11 pls., 1 fig.

TECHNICAL PAPER 9. The status of the gas producer and of the internal combustion engine in the utilization of fuels, by R. H. Fernald. 1912. 42 pp., 6 figs.

TECHNICAL PAPER 16. Deterioration and spontaneous heating of coal in storage, a preliminary report, by H. C. Porter and F. K. Ovitz. 1912. 14 pp.

TECHNICAL PAPER 34. Experiments with furnaces for a hand-fired return tubular boiler, by S. B. Flagg, G. C. Cook, and F. E. Woodman. 1914. 32 pp., 1 pl., 4 figs.

Generated on 2024-09-28 16:16 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

TECHNICAL PAPER 35. Weathering of the Pittsburgh coal bed at the experimental mine near Bruceton, Pa., by H. C. Porter and A. C. Fieldner. 1914. 35 pp., 14 figs.

TECHNICAL PAPER 50. Metallurgical coke, by A. W. Belden. 1913. 48 pp., 1 pl., 23 figs.

TECHNICAL PAPER 55. The production and use of brown coal in the vicinity of Cologne, Germany, by C. A. Davis. 1913. 15 pp.

TECHNICAL PAPER 76. Notes on the sampling and analysis of coal, by A. C. Fieldner. 1914. 59 pp., 6 figs.

TECHNICAL PAPER 80. Hand firing soft coal under power-plant boilers, by Henry Kreisinger. 1915. 83 pp., 32 figs.

TECHNICAL PAPER 97. Saving fuel in heating a house, by L. P. Breckenridge and S. B. Flagg. 1915. 35 pp., 3 figs.

TECHNICAL PAPER 98. Effect of low-temperature oxidation on the hydrogen in coal and the change of weight of coal in drying, by S. H. Katz and H. C. Porter. 1917. 16 pp., 2 figs.

TECHNICAL PAPER 123. Notes on the uses of low-grade fuel in Europe, by R. H. Fernald. 1915. 37 pp., 4 pls., 4 figs.

TECHNICAL PAPER 133. Directions for sampling coal for shipment or delivery, by G. S. Pope. 1917. 15 pp., 1 pl.

TECHNICAL PAPER 148. The determination of moisture in coke, by A. C. Fieldner and W. A. Selvig. 1917. 13 pp.

TECHNICAL PAPER 170. The diffusion of oxygen through stored coal, by S. H. Katz. 1917. 49 pp., 1 pl., 27 figs.

TECHNICAL PAPER 172. Effects of moisture on the spontaneous heating of stored coal, by S. H. Katz and H. C. Porter. 1917. 25 pp., 1 pl., 8 figs.

PUBLICATIONS THAT MAY BE OBTAINED ONLY THROUGH THE SUPERINTENDENT OF DOCUMENTS.

BULLETIN 2. North Dakota lignite as a fuel for power-plant boilers, by D. T. Randall and Henry Kreisinger. 1910. 42 pp., 1 pl., 7 figs.

BULLETIN 3. The coke industry of the United States as related to the foundry, by Richard Moldenke. 1910. 32 pp. 5 cents.

BULLETIN 4. Features of producer-gas power-plant development in Europe, by R. H. Fernald. 1910. 27 pp., 4 pls., 7 figs. 10 cents.

BULLETIN 8. The flow of heat through furnace walls, by W. T. Ray and Henry Kreisinger. 1911. 32 pp., 19 figs. 5 cents.

BULLETIN 9. Recent development of the producer-gas power plant in the United States, by R. H. Fernald. 82 pp., 2 pls. 15 cents.

BULLETIN 11. The purchase of coal by the Government under specifications, with analyses of coal delivered for the fiscal year 1908–9, by G. S. Pope. 80 pp. 10 cents.

BULLETIN 13. Résumé of producer-gas investigations, October 1, 1904, to June 30, 1910, by R. H. Fernald and C. D. Smith. 1911. 393 pp., 12 pls., 250 figs. 65 cents.

BULLETIN 14. Briquetting tests of lignite at Pittsburgh, Pa., 1908–9, with a chapter on sulphite-pitch binder, by C. L. Wright. 1911. 64 pp., 11 pls., 4 figs. 15 cents.

BULLETIN 18. The transmission of heat into steam boilers, by Henry Kreisinger and W. T. Ray. 1912. 180 pp., 78 figs. 20 cents.

BULLETIN 21. The significance of drafts in steam-boiler practice, by W. T. Ray and Henry Kreisinger. 64 pp., 26 figs. 10 cents.

Generated on 2024-09-28 16:16 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

BULLETIN 22. Analyses of coals in the United States, with descriptions of mine and field samples collected between July 1, 1904, and June 30, 1910, by N. W. Lord, with chapters by J. A. Holmes, F. M. Stanton, A. C. Fieldner, and Samuel Sanford. 1912. Part I, Analyses, pp. 1–321; Part II, Descriptions of samples, pp. 321–1129. 85 cents.

BULLETIN 23. Steaming tests of coals and related investigations, September 1, 1904, to December 31, 1908, by L. P. Breckenridge, Henry Kreisinger, and W. T. Ray. 1912. 380 pp., 2 pls., 94 figs. 50 cents.

BULLETIN 27. Tests of coal and briquets as fuel for house-heating boilers, by D. T. Randall. 44 pp., 3 pls., 2 figs. 10 cents.

BULLETIN 30. Briquetting tests at the United States fuel-testing plant, Norfolk, Va., 1907–8, by C. L. Wright. 41 pp., 9 pls. 15 cents.

BULLETIN 31. Incidental problems in gas-producer tests, by R. H. Fernald, C. D. Smith, J. K. Clement, and H. A. Grine. 29 pp., 8 figs. 5 cents.

BULLETIN 33. Comparative tests of run-of-mine and briquetted coal on the torpedo boat *Biddle*, by W. T. Ray and Henry Kreisinger. 50 pp., 10 figs. 15 cents.

BULLETIN 34. Tests of run-of-mine and briquetted coal in a locomotive boiler, by W. T. Ray and Henry Kreisinger. 33 pp., 9 figs. 5 cents.

BULLETIN 35. The utilization of fuel in locomotive practice, by W. F. M. Goss. 29 pp., 8 figs. 5 cents.

BULLETIN 37. Comparative tests of run-of-mine and briquetted coal on locomotives including torpedo-boat tests, and some foreign specifications for briquetted fuel, by W. F. M. Goss. 58 pp., 4 pls., 35 figs. 15 cents.

BULLETIN 40. The smokeless combustion of coal in boiler furnaces, with a chapter on central heating plants, by D. T. Randall and H. W. Weeks. 188 pp., 40 figs. 20 cents.

BULLETIN 41. Government coal purchases under specifications, with analyses for the fiscal year 1909–10, by G. S. Pope, with a chapter on the fuel-inspection laboratory of the Bureau of Mines, by J. D. Davis. 1912. 97 pp., 3 pls., 9 figs. 15 cents.

BULLETIN 63. Sampling coal deliveries and types of Government specifications for the purchase of coal, by G. S. Pope. 1913. 68 pp., 4 pls., 3 figs. 10 cents.

BULLETIN 109. Operating details of gas producers, by R. H. Fernald. 1916. 74 pp. 10 cents.

BULLETIN 116. Methods of sampling delivered coal, and specifications for the purchase of coal for the Government, by G. S. Pope. 1916. 64 pp., 5 pls., 2 figs. 15 cents.

TECHNICAL PAPER 1. The sampling of coal in the mine, by J. A. Holmes. 1911. 18 pp., 1 fig. 5 cents.

TECHNICAL PAPER 20. The slagging type of gas producer, with a brief report of preliminary tests, by C. D. Smith. 1912. 14 pp., 1 pl. 5 cents.

TECHNICAL PAPER 63. Factors governing the combustion of coal in boiler furnaces, a preliminary report, by J. K. Clement, J. C. W. Frazer, and C. E. Augustine. 1914. 46 pp., 26 figs. 10 cents.

TECHNICAL PAPER 65. A study of the oxidation of coal, by H. C. Porter. 1914. 30 pp., 12 figs. 5 cents.

TECHNICAL PAPER 114. Heat transmission through boiler tubes, by Henry Kreisinger and F. K. Ovitz. 1915. 36 pp., 23 figs. 10 cents.

TECHNICAL PAPER 137. Combustion in the fuel bed of hand-fired furnaces, by Henry Kreisinger, F. K. Ovitz, and C. E. Augustine. 1916. 76 pp., 2 pls., 21 figs.

Generated on 2024-09-28 16:19 GMT / https://hdl.handle.net/2027/njp.32101054990401
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY